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# Vulnerability/Lethality Server High Level Architecture (HLA) Interface Control Document

**by Geoffrey C. Sauerborn**

**ARL-MR-0575** **February 2004**

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# Vulnerability/Lethality Server High Level Architecture (HLA) Interface Control Document

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**14. ABSTRACT**

The U.S. Army Research Laboratory (ARL) vulnerability/lethality table look-up server has gone through several iterations of development since first introduced in 1997 (then as the distributed interactive simulation [DIS] lethality communications server). These development iterations represented migration from its original transmission control protocol/internet protocol client/server communication form based in DIS, to a combined DIS-high level architecture (HLA) form used during the 2001 Research, Development, and Engineering Center (RDEC) Federation "CalEx" (calibration experiments) and onto this current form that is all HLA and was designed for the RDEC command "1stApp" (First Application) experiment 2003 and presented in this report.

This interface control document (ICD) describes the current state of exposed interface control components of the ARL vulnerability/lethality table look-up server (the server). The ICD describes the interface to an existing implementation of the server (with its look-up table capability). The interface described in this report includes an area that provides for further expansion, allowing delivery of damage descriptions from near real-time physics-based vulnerability models (future dynamic calculation capability).

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# 1. Introduction

The U.S. Army Research Laboratory (ARL) vulnerability/lethality table look-up server has gone through several iterations of development since first introduced in 1997 (then as the distributed interactive simulation [DIS] lethality communications server) (*1*). These development iterations represented migration from its original transmission control protocol/internet protocol client/ server communication form based in DIS, to a combined DIS-high level architecture (HLA) form used during the 2001 Research, Development, and Engineering Center (RDEC) Federation "CalEx" (calibration experiments) (*2*) and onto this current form that is all HLA and was designed for the RDEC command "1stApp" (First Application) experiment 2003 and presented in this report (*3,4,5,6*).

This interface control document (ICD) describes the current state of exposed HLA interface control components of the ARL vulnerability/lethality table look-up server (the server). The ICD describes the interface to an existing implementation of the server (with its look-up table capability). The interface described in this report includes an area that provides for further expansion, allowing delivery of damage descriptions from near real-time physics-based vulnerability models (future dynamic calculation capability).

# 2. Scope

The HLA specification requires an object model template (OMT). This ICD describes and explains the server's OMT object model components (*7, 8*). The server has an HLA interface. HLA object model components that are unique to the server are described in this ICD. Ancillary but required objects are only mentioned and referenced (all these are from the real-time platform reference federation object model (RPR FOM) (*9*).

# 3. Simulation Object Model (SOM) Intent

The server's SOM is designed to simply advertise its existence (via a small "service description" object class shown in table 1); the bulk of the SOM and work is then conducted via HLA interactions.

### 3.1 SOM Object Classes

The idea behind this general object class structure is that a future architecture would consist of various "services". Thus, a "root service" should exist. "Service" fills this function. A LethalityServer as well as other services would stem from this node. MobilityServer and TerrainServer are not used by the LethalityServer. They are only conceptual examples of other services to illustrate this intended structure.

Table 1. Lethality server class structure

| Class1 | Class2 |
|---|---|
| Service (PS) | LethalityServer (PS) |
| | MobilityServer (N) |
| | TerrainServer (N) |

Table 2 names and explains the variables (attributes) within the service class structure.

Table 2. Object classes (server published)

| Object Class | Attribute | Data Type | Attribute Description |
|---|---|---|---|
| Service (PS) | Type | Simulation Services Enum32 | Name or type of a specific service. Intent: There may be several services of a particular class, each with various missions or degrees of fidelity. "Type" distinguishes one from another. (Type Example values: LethalityServer_Table Lookup (1) LethalityServer_DynamicCalculation (2) ). See table 9 Enumerations. |
| Service. Lethality Server (PS) | VersionID | String | Revision control identifier. Intent: The server optionally accepts queries and delivers results based on a conventional protocol configured to a particular VersionID. Subscribing federates should warn if the revision ID (VersionID) is an unexpected value. |

The other object class subscribed to is the BaseEntity.PhysicalEntity root from the RPR FOM (see table 3). The server monitors entity information here to know a target's orientation and position at the time of munition detonations.

Table 3. Ancillary but required object classes (from RPR FOM)

| Class1 | Class2 |
|---|---|
| BaseEntity [26] (S) | PhysicalEntity (S) |

### 3.2 SOM Interaction Classes

The lethality server's interaction class structure is shown in table 4. There is a "root service" interaction class for the same reason given for the "root service object class" (see table 1). That is, it is a logical point of entry for service-related interactions.

Table 4. Lethality server interaction class structure

| Interaction1 | Interaction2 | Interaction3 | Interaction4 | Interaction5 |
|---|---|---|---|---|
| Service (N) | Query (N) | Lethality (N) | TableLookUp (IS) | Parameters (IS) |
| | | | | Result (IS) |
| | | | DynamicCalculation (N) | Parameters (N) |
| | | | | Result (N) |
| | BroadcastInfo (N) | Lethality (N) | TableLookUp (IS) | Result (IS) |
| | | | DynamicCalculation (N) | Result (N) |

The general concept of this interaction class structure is to embody the rudiments of a query-response mechanism. This query-response is portrayed in figure 1.

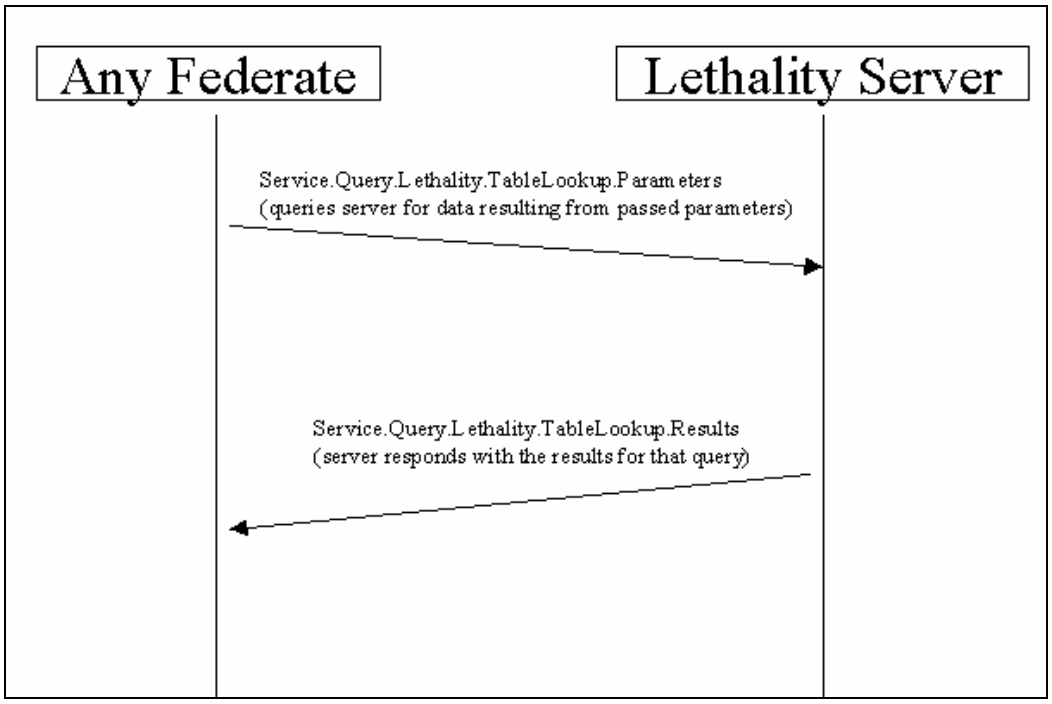


Figure 1. Query and response interaction.

In general, most of the time, the server is broadcasting damage resulting from some event. It does so by sending interaction data along the Service.BroadcastInfo.Lethality interaction hierarchy object structure, namely, InteractionRoot.Service.BroadcastInfo.Lethality.Table LookUp.Result. Subscribers to this interaction will receive a notification for every event that

could cause damage. Currently, the only event triggering a Lethality.TableLookUp.Result interaction is the RPR FOM "MunitionDetnonation" interaction. This is portrayed in figure 2, and table 5 names and explains the variables (parameters) within the Service.Broadcast Info.Lethality.TableLookUp interaction object structure.

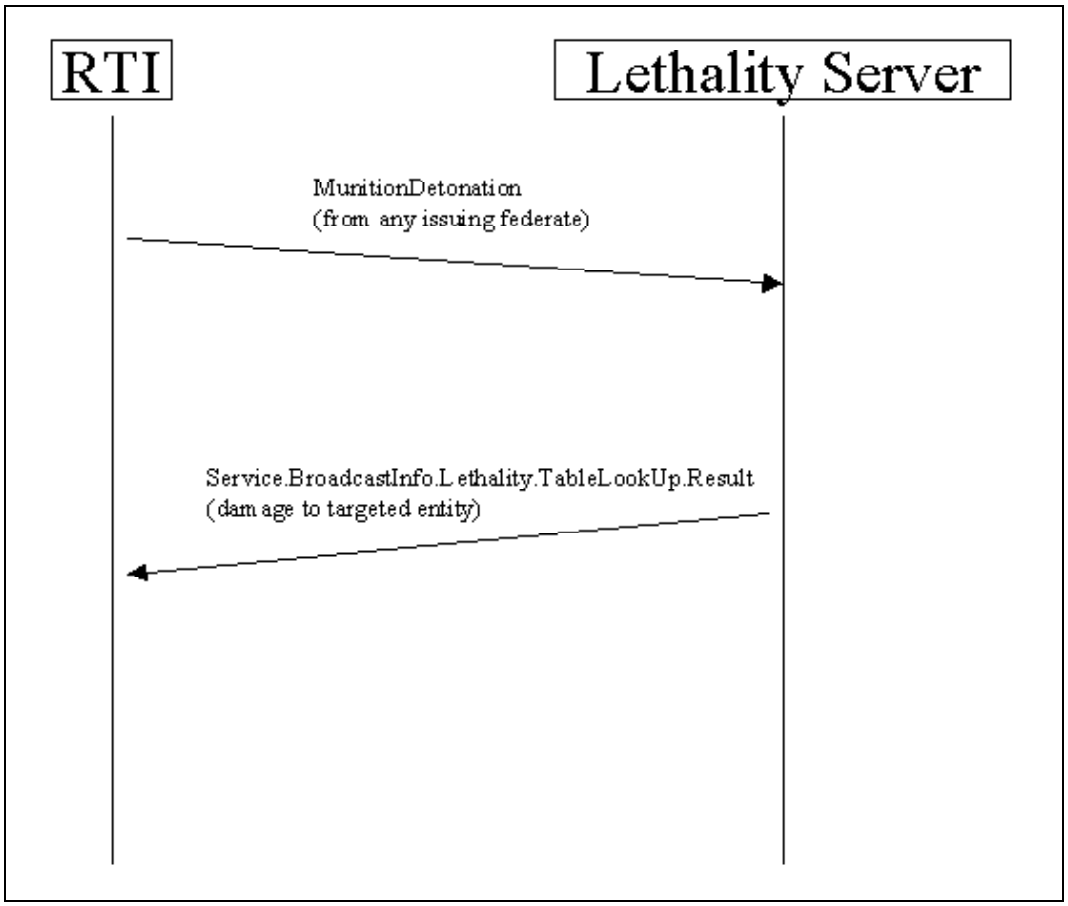


Figure 2. Resulting damage interaction.

### 3.3 Assumptions

- Receiving applications are expected to locally filter the messages based on their interest. This is because all results are broadcast. Only a tiny fraction of these will apply to any one entity (unless that entity is very unlucky).

- Affected entities are expected to logically "OR"[1] the resulting damage with their current damage state. This is because the currently implemented server does not use an entity's current state when calculating damage. (This is because the underlying look-up tables generally assume damage on a "first hit" basis.) The result is that it is possible to receive a mobility-firepower kill (MF-Kill) followed by a second shot delivering a mobility kill (M-Kill). If the entity were to blindly follow the server, its overall state would improve after the second shot!

[1] That is, entities are expected to combine a new damage state with their existing state.

Table 5. Lethality server interaction: "service.broadcastinfo.lethality.tablelookup" (server published)

| Interaction Object | Parameter | Data Type | Parameter Description |
|---|---|---|---|
| Service. Broadcast Info. Lethality. Table LookUp | Event [Identifier] ID | Event Identifier Struct | An ID, generated by the issuing federate, used to associate related fire and detonation events. This ID identifies the detonation event whose results are about to be broadcast by the server. The "EventIdentifierStruct" data type is reused from the RPR FOM. |
| Service. Broadcast Info. Lethality. Table LookUp | DISevent Identifier ID | DISEvent Identifier Struct | The DIS event identifier record. This is the triple unsigned short used to identify events in the DIS (IEEE 1278) specification. It is here for DIS backward compatibility. If a querying federate is able to determine the DIS event (i.e., if it is monitoring raw DIS traffic as well as HLA traffic), then this field could be useful to a subscribing federate. However, there is no guarantee that the server too is able to monitor raw DIS traffic. If DIS traffic is monitored, the server will do its best to reconstruct the event ID; however, as different DIS-HLA gateways translate RPR FOM EventIDs to the "DIS Triple," there can be no guaranteed linkage between the DISeventID and EventIdentifier ID |
| Service. Broadcast Info Lethality. Table LookUp. Result (PS) | Instan-taneous Damage | Damage Status Enum32 | This is the instantaneous result of the subject damage event provided by the lethality server. It contains the results of the damage event (identified by TableLookUp.EventID) against the target (identified by TableLookup.Result.EntityID). Results are "instantaneous" because they are not cumulative (server contains no "memory" of the previous damage state) and they might not be repeatable. The simulating entity must logically "or" this damage result with its previous damage state. |
| | EntityID | Entity IdentifierS truct | The ID of the entity being analyzed for vulnerability to the subject damage event (this damage event is identified by TableLookup.EventIdentifierID).<br>The "EntityIdentifierStruct" is reused from the RPR FOM. |
| | Entity Type | Entity Type Struct | This is the type identifier for the entity that is under threat. (Note: this information might be indirectly available via the EventIdentifierID parameter but is supplied here for convenience.) |
| | Threat Type | Entity Type Struct | The type of munition or damage device used to attack the threatened entity. (As with "EntityType," this is provided for convenience and to avoid ambiguity.) |
| | Error | Boolean | If TRUE, then a valid look-up table or other data source could ***not*** be retrieved, and the results shown in the "InstantaneousDamage" parameter therefore have **NO** validity. If FALSE, then a data source was found and no other errors were detected. (See the parameter ErrorMessage.) |
| | Error Message | String | If an error occurred (parameter "Error" == TRUE) then this field may (or may not) supply a helpful error message in human readable text. |
| | Results Flag | LethalityV alue FlagEum3 2 | Tells more about the instantaneous result returned from a lethality query (or broadcast) interaction. By default, the server always returns a result from a query, but whenever ResultsFlag has any value other than "Success_NoError," then that result is erroneous. This flag's returned value can provide hints as to the error's source. (See ResultsFlagText.) |
| | Results FlagText | String | Provides a very short text description of the results flag. (Basically, this is the text representation of the "ResultsFlag" enumerated LethalityValueFlagEnum32 value.) |

The "Service.Query.Lethality.TableLookUp.Parameters" interaction class is where federates may query a lethality server for more specific information. A federate makes its query by issuing this interaction. The server responds by finding the results based on the passed interaction parameters and returns the results. Table 6 names and explains these parameters.

The Service.Query.Lethality.TableLookUp.Results is the area where results of the table look-up query are provided. Table 7 describes these returned parameters. The type of results returned depends on what was queried (See: Service.Query.Lethality.TableLookUp.Parameters, table 6).

Table 6. Lethality server interaction: "service.query.lethality.tablelookup.parameters" (server subscribed)

| Interaction Object | Parameter | Data Type | Parameter Description |
|---|---|---|---|
| Service. Query. Lethality. TableLookUp | Event IdentifierID | Event Identifier Struct | An ID generated by the issuing federate, used to associate related fire and detonation events. This is the identifier that identifies a detonation event and is the subject of the lethality query. |
| | DISevent IdentifierID | DISEntity Identifier Struct | The DIS event identifier record. This is the triple unsigned short used to identify events in the DIS (IEEE 1278) specification. If a querying federate is able to determine the DIS event (i.e., if it is monitoring raw DIS traffic as well as HLA traffic), then this field could be filled. However, there is no guarantee that the server is able to monitor raw DIS traffic; thus, an error might be returned in the "Query.Lethality.Tablelookup.Result" interaction response. |
| Service. Query. Lethality. TableLookUp .Parameters | EntityID | Event Identifier Struct | The ID of the entity being analyzed for vulnerability to the subject damage event (this damage event is identified by TableLookup.EventIdentifierID). |
| | QueryID | string | An identifier provided by the querying federate. This identifier is returned with the query result in the TableLookup.Result.QueryID field. |
| | Special Query Parameters | Query Lethality Table Lookup Special Parameters Struct | This data structure is used to query the server for many types of information beyond the normal M, F, MF, K damage result. It can be used to view the initial conditions used by the server, display raw probability distributions (not just the outcome) or other information. If all the client wants is MFK results, then these parameters should be set to false. |

Table 8 lists interactions defined in the RPR FOM to which the server subscribes. These are not explained, only referenced.

Enumerated data types and complex data types developed for the server are explained in tables 9 and 10, respectfully. Other enumerations are defined in the RPR FOM: DamageStatusEnum32, WarheadType16, FuseTypeEnum16, DetonationResultCodeEnum8, ForceIdentifierEnum8, MarkingEncodingEnum8, EventTypeEnum32.

Table 10 displays lethality server-defined complex data types. When executing a server query, querying federates set the Boolean "QueryLethalityTableLookupSpecialParametersStruct.

ProbabilityDistributionQuery" to TRUE if they wish to receive the five floating point numbers that represent the cumulative likelihood of only an M-Kill, only a firepower kill (F-Kill), an MF-Kill, catastrophic kill (K-Kill), and no damage. These values are "additive" (also known as thermometer redistribution). This means that within the set of five returned values, the first value is the probability of an M-Kill; the second floating point value returned is the sum of M-Kill + F-Kill; the third value is the sum of M-Kill + F-Kill + MF-Kill, and so forth.

Table 7. Lethality server interaction: "service.query.lethality.tablelookup.results" (server published)

| Interaction Object | Parameter | Data Type | Description |
|---|---|---|---|
| Service. Query. Lethality. TableLookup .Results. | Instantane-ousDamage | Damage StatusEnum 32 | This is the instantaneous result of the subject damage event provided by the lethality server. It contains the results of the damage event (identified by TableLookUp.EventID) against the target (identified by TableLookup.EntityID). Results are "instantaneous" because they are not cumulative (the server does not consider the previous entity's state when issuing damage from a new detonation), and the damage may not be repeatable. That is, repeated calls for the same detonation event can result in different outcomes (albeit drawn from the same distribution of outcomes). |
| | QueryID | string | An identifier returned by the server. This identifier was originally provided by the querying federate along with the query in the Service.Query.TableLookup.Parameters.QueryID field. The server returns the same value placed by the querying federate so that the federate may know the supplied result is in response to his query and not another's. |
| | Error | Boolean | If TRUE, then a valid look-up table or other data source could ***not*** be retrieved and the results shown in the "InstantaneousDamage" parameter therefore have **NO** validity. If FALSE, then a data source was found and no other errors were detected. (See the parameter ErrorMessage.) |
| | Error Message | string | If an error occurred (parameter "Error" == TRUE), then this field may (or may not) supply a helpful error message in human readable text. |
| | ResultsFlag | Lethality ValueFlag Eum32 | Tells more about the instantaneous result returned from a lethality query (or broadcast) interaction. By default, the server always returns a result from a query, but whenever ResultsFlag has any value other than "Success_NoError," then that result is erroneous. This flag's returned value can provide hints as to the error's source. (See ResultsFlagText.) |
| | ResultsFlag Text | string | Provides a very short text description of the results flag. (Basically, this is the text representation of the "ResultsFlag" enumerated LethalityValueFlagEnum32 value; see table 9 Enumerations.) |

Table 8. RPR FOM interactions (server subscribed)

| Interaction Object | How Used | Reference |
|---|---|---|
| MunitionDetonation | 1.) Server records internally.<br>2.) Triggers server to broadcast the resulting damage (BroadcastInfo. Lethality.TableLookUp.Result). | RPR FOM |
| WeaponFire | 1) Server records.<br>2) Under certain circumstances, server may use some of this information to calculate MunitionDetonation damage (e.g., to resolve ambiguities in the range a munition was fired from). | RPR FOM |

Table 9. Enumerations

| Identifier | Enumerator | Representation |
|---|---|---|
| SimulationServicesEnum32 | LethalityServer_TableLookup | 1 |
| | LethalityServer_DynamicCalculation | 2 |
| | TerrainServer_DataPointQueries | 3 |
| | SerialNumberGenerator | 4 |
| LethalityValueFlagEnum32 | Success_NoError | 0 |
| | Error_Unknown | 1 |
| | Error_NoLookupTableFound | 2 |
| | Error_CurruptTable | 3 |
| | Error_MissingEnvironmentData | 4 |

If a querying federate wishes to examine all initial conditions used to determine the vulnerability calculation, then "QueryLethalityTableLookupSpecialPareamtersStruct.InitialConditionsQuery" is set TRUE. The server then will return an ASCII (American Standard Code for Information Interchange) human readable list of its internal parameter values used for the subject detonation event. See "DISEventIdentifierID" in table 6 for an explanation of the DISEventIdentifierStruct. Complex data types defined for use by the server are shown in table 10.

Table 10. Complex data types

| Complex Datatype | Field Name | Datatype | Cardinality |
|---|---|---|---|
| QueryLethalityTableLookupSpecialParametersStruct | ProbabilityDistributionQuery | boolean | 1 |
| | InitialConditionsQuery | boolean | 1 |
| QueryLethalityTableLookupSpecialResultStruct | ProbabilityDistributionMFK | float | 5 |
| | InitialConditions | string | 1 |
| DISEventIdentifierStruct | host | unsigned sho | 1 |
| | application | unsigned sho | 1 |
| | event_id | unsigned sho | 1 |

Other server-used complex data types are defined in the RPR FOM: EventIdentifierStruct, Entity IdentifierStruct, EntityTypeStruct, RTIObjectIdStruct, RelativePositionStruct, VelocityVectorStruct, WorldLocationStruct, MarkingStruct, OrientationStruct, and AccelerationVectorStruct. AngularVelocityVectorStruct and ArticulatedParameterStruct are currently not used.

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